ALLIED
ORDNANCE
PUBLICATION

AOP-34
(Edition 1)

NATO INTERNATIONAL STAFF - DEFENCE SUPPORT DIVISION

VIBRATION TESTS METHOD AND SEVERITIES FOR MUNITIONS CARRIED IN TRACKED VEHICLES

AOP-34

NOVEMBER 99

AOP-34
(Edition 1)

ALLIED
ORDNANCE
PUBLICATION

VIBRATION TESTS METHOD AND SEVERITIES FOR MUNITIONS CARRIED IN TRACKED VEHICLES

AOP-34

NOVEMBER 1999

NORTH ATLANTIC TREATY ORGANIZATION

MILITARY AGENCY FOR STANDARDIZATION (MAS)

NATO LETTER OF PROMULGATION

November 1999

1. AOP-34 (Edition 1) - VIBRATION TESTS METHOD AND SEVERITIES FOR MUNITIONS CARRIED IN TRACKED VEHICLES is a NATO/PfP UNCLASSIFIED publication. The agreement of nations to use this publication is recorded in STANAG 4242.

2. AOP-34 (Edition 1) is effective upon receipt.

A. GRØNHEIM
Major General, NOAF
Chairman, MAS

NATION	SPECIFICATION RESERVATIONS

RECORD OF CHANGES

Change Date	Date Entered	Effective Date	By Whom Entered

TABLE OF CONTENTS

VIBRATION TESTS METHOD AND SEVERITIES FOR MUNITIONS CARRIED IN TRACKED VEHICLES

1. SCOPE

1.1. This Allied Ordnance Publication (AOP), is covered by STANAG 4242, Vibration Tests Method and Severities for Munitions Carried in Tracked Vehicles, and contains a vibration test method and test severities for munitions carried in such vehicles. The AOP addresses vibration environments associated with installed munitions in tracked vehicles, either within racks or directly attached to the vehicle structure. It also addressees vibration environments where munitions are transported in tracked vehicles as secured cargo.

1.2. This AOP is not applicable for munitions transported as loose cargo within tracked vehicles (see STANAG 4370, AECTP-400, Method 406 Loose Cargo).

1.3. This AOP is compatible with STANAG 4370, AECTP-400, Method 401 Vibration. It contains a test method directly relevant to munitions when subjected to tracked vehicle environments, and also gives explicit instructions on test severities and their selection.

1.4. This AOP covers the selection of test types for particular operational scenarios and their associated severities, the information that must be included in the test instruction, the test installation requirements and the order of testing.

1.5. Further information on the characteristics of the tracked vehicle environment is contained in Annex A. The derivation of test severities from measured data is the subject of Annex B. Relevant definitions are given in Annex C.

2. RATIONALE

2.1. General

2.1.1. This test method and its associated severities is used to represent the effects of vibration environments incurred by munitions during tracked vehicle operations. The method and severities should be used to support assessments of the ability of munitions to withstand tracked vehicle vibration environments without unacceptable degradation of their functional and safety performance.

2.1.2. The vibration environment associated with tracked vehicles is characterised by a wide band random frequency spectrum having narrow band components at higher amplitudes. The wide band frequency components arise from the vehicle's dynamic responses caused by its motion over the terrain and transmitted by its power unit, drive train, etc. The regions with higher amplitudes arise from the impact of successive track plates with the ground and correspond to the fundamental frequency and harmonics which are directly related to the speed of the vehicle.

2.1.3. The vibration characteristics of tracked vehicles are presented in detail in Annex A. Due account is taken of these characteristics in this document and particularly in the selection of the test types and test severities.

2.2. Test Types

2.2.1. The following types of test are appropriate for dealing with tracked vehicle vibration.

a. Swept frequency narrow band random vibration on wide band random vibration.

b. Swept frequency sinusoidal vibration on wide band random vibration.

A brief description of both types is given in paragraph 3.

2.2.2. Given the inherent limitations of (a) and (b) above, evaluation of field measured data suggests that, in general, swept frequency narrow band vibration on wide band vibration more closely simulates the tracked vehicle vibration environment. Consequently, for standardisation, test type (a) is generally preferred.

2.2.3. The swept frequency sinusoidal vibration on wide band random vibration test procedure type (b) is an acceptable alternative. It is the recommended test where harmonic phase relationships for the track patter vibration components may have a significant effect on the munition being tested. However, this document does not yet include a procedure for this relationship. (A procedure will be developed for a future edition of this AOP.)

2.3. Test severities

2.3.1. Many munition failure criteria are difficult to quantify. Therefore, safety considerations dictate that the maximum vibration levels observed during field measurement trials, or predicted by analysis, must be encompassed within the selected test severity.

2.3.2. Although it is recognised that vibration test severities are strongly influenced by the particular tracked vehicle type, munition type, vehicle location, container type, etc, it is impractical to include all such combinations in this document. However, an evaluation of many combinations suggests that the following categories provide an acceptable description of the range of vibration severities arising from tracked vehicles.

a. Munitions transported as secured cargo.

b. Munitions installed in bustle racks or directly in turrets.

c. Munitions installed in racks within hulls.

d. Munitions on sponsons or installed directly in hulls.

Severities for these categories are presented in paragraph 10.

2.3.3. Munitions may need to be transported in a tracked vehicle as secured cargo in their appropriate packaging prior to their installation, perhaps in a different tracked vehicle. In such cases it may be necessary to conduct two vibration tests, one for each condition. The tests may require different test installations and specimen assemblies in addition to different vibration test severities.

2.3.4. It may be necessary to undertake a test to cover munition transportation as loose cargo within tracked vehicles (see STANAG 4370, AECTP-400 Method 406 Loose Cargo). Speed related periodics are present in loose cargo data from tracked vehicles which are not reproduced on the current package testers. Information on fatigue damage from carriage in tracklaying vehicles can be obtained from secured cargo or installed equipment vibration tests whereas chafing type damage can be evaluated using loose cargo testing procedures.

2.3.5. Whenever practicable, test severities should be selected after consideration of measured data acquired from field trials using the specified tracked vehicle and simulation of the operational scenarios derived from the "Manufacture to Target" Sequence.

2.3.6. It is particularly important to use field data where a precise simulation using tailored test severities is the aim. In such cases, it is essential that sufficient field data is obtained to describe adequately the local vibration inputs to the munitions and also the responses experienced by the munitions. The derivation of vibration test severities from measured data is the subject of Annex B. This annex gives one method of developing a vibration test schedule based on fatigue equivalence.

2.3.7. Although tailored test severities are applicable for many installations, they are not appropriate for munitions installed in racks, where the racks can be positioned in any one of several sites within a particular type of tracked vehicle, or in several different types of tracked vehicle. In these cases the relevant levels specified in paragraph 10 should be used.

2.3.8. Experience suggests that the severity levels quoted in this document accommodate vibration responses for most tracked vehicles. However, no assurance can be given that these levels encompass all vibration responses for all operational conditions for all tracked vehicles. Therefore, for a particular situation, if there is reasonable doubt that the vibration responses may not be encompassed then field measurements should be taken.

2.3.9. The severities addressed in this document relate only to vibration. In some cases, examination of the field data may indicate that shock testing may be necessary to cover high acceleration levels arising from some cross-country conditions. Further information on shock levels is given in STANAG 4370, AECTP-200.

2.4. Test sequence

2.4.1. Many munitions are sensitive to the application of combined environments. Therefore, it is essential that a munition which is likely to encounter in service a combination of environments, such as vibration and temperature, and which also is likely to be sensitive to such environments, is tested to the relevant most adverse combinations simultaneously.

2.4.2. Consequently, munitions are tested at the extremes of temperature likely to be encountered during service. The test temperatures should be based upon the climatic zones specified in STANAG 2895 in which the munition is to be deployed. Where appropriate they should also include allowances for effects such as ventilation or screening, which can influence the temperature experienced by the munition.

2.4.3. Where it is necessary to evaluate the cumulative effects of vibration together with other relevant environments, a single test item should be exposed sequentially to combinations of all relevant environmental conditions. The order of application of tests should be made compatible with the Manufacture to Target Sequence. When conducting sequential tests due account must also be taken of the assembled state of the munition (eg: its packaged state).

2.5. Assessment

2.5.1. Test results rarely provide the complete evidence for munition approval. One reason is that the test conditions do not completely replicate the environments. Therefore, a supporting assessment statement is usually necessary to complement the test results. This statement will contain the total evidence in response to the environmental requirement. The approval authority will deliberate on this evidence and make its recommendations regarding the munition's safety and suitability for service.

2.5.2. When field measurements are acquired and used to select the test method and derive test severities, the supporting statement should include estimates of the effects of parameters not accommodated in the field trials, such as the influence of track wear, vehicle to vehicle variations, test track shortcomings, standard of hardware tested, climatic conditions, etc.

2.5.3. When the severities in this document are used for the test the statement should include, for example, the reasons for the choice of levels and durations, and any relevant assurances that the test levels selected will rarely be exceeded in service.

3. TYPES OF VIBRATION

3.1. General

3.1.1. A brief definition of the generic types of vibration together with a listing of the parameters to describe the vibration severity for each generic type is given in the following paragraphs.

3.2. Swept frequency narrow band random vibration on wide band random vibration

3.2.1. Swept frequency narrow band random vibration on wide band random vibration can be defined as one or more, sometimes up to 5, narrow bands of random vibration swept over a frequency range and superimposed on a background of wide band random vibration.

3.2.2. In order to replicate the effects of track patter, the narrow band representing the fundamental frequency must traverse the full frequency range up to that experienced at the vehicle maximum speed. The upper frequency can be predicted from the track geometry. At slow speeds the amplitude of the fundamental frequency may fall below the level of the background wide band random test level. The speed at which the fundamental frequency becomes significant can only be determined by measurement.

3.2.3. Should measured data not be available, it may be necessary to sweep the full excursion of F_1, F_2 and F_3 depicted in Figures 1 to 4. Most modern digital vibration controllers now have mixed mode capabilities and can perform the full frequency sweep required by the figures.

3.2.4. A composite vibration severity is defined by the following:

a. The Acceleration Spectral Density (ASD) spectrum profile of the wide band random vibration.

b. The test frequency range of the wide band random vibration.

c. The ASD spectrum profile(s) of the narrow band random vibration.

d. The overall root mean square (rms) acceleration level of the combined narrow bands with the wide band random spectrum over the test frequency range.

e. The swept frequency range.

f. The sweep rate and type of sweep.

g. The duration of the test.

3.3. Swept frequency sinusoidal vibration on wide band random vibration

3.3.1. Swept frequency sinusoidal vibration on wide band random vibration can be defined as one or more sinusoids, sometimes up to 5, swept over a frequency range, and superimposed on a random vibration background.

3.3.2. In order to replicate the effects of track patter, the sine tone representing the fundamental frequency must traverse the full frequency range up to that experienced at the vehicle maximum speed. The upper frequency can be predicted from the track geometry. At slow speeds the amplitude of the fundamental frequency may fall below the level of the background wide band random test level. The speed at which the fundamental frequency becomes significant can only be determined by measurement.

3.3.3. Recent advances in proprietary software packages for digital vibration controllers now allow for three or more sinusoids to be swept over the full frequency range required by Figures 1 to 4.

3.3.4. A composite vibration severity is defined by the following parameters:

a. The ASD spectrum profile of the wide band random vibration.

b. The test frequency range of the wide band random vibration.

c. The rms level of the wide band random vibration over the test frequency range.

d. The amplitude(s)/frequency profile(s) of the sinusoid(s).

e. The sweep rate and type of sweep.

f. The duration of the test.

4. CONTROL STRATEGY OPTIONS

4.1. Strategy

4.1.1. The vibration excitation is controlled within specified bounds by sampling the vibratory motions of the test item at specific locations. These locations may be at, or in close proximity to, the test item fixing points (controlled input tests) or at defined points on the test item (controlled response tests). The vibratory motions may be sampled at a single point (single point control), or at several locations (multi-point control).

4.1.2. The choice of control strategy option could be influenced by:

a. The results of preliminary vibration surveys carried out on equipment and fixtures.

b. The difficulties of meeting the test specifications within the specified tolerances.

c. The capability of the test facility.

4.2. Multiple point control (average) option

4.2.1. This option can be used when the preliminary vibration survey shows that inputs to the test item vary significantly between fixing points. The control points, usually two or three, will be selected using the same criteria listed in paragraph 4.4.1 for the single control point option.

4.2.2. However, the control for:

a. Random will be based on the average of the ASD's of the control points selected.

b. Sine will be based on the average of the peak response values at the control points selected. If noisy signals are encountered, tracking filters may be necessary.

4.3. Multiple point control (maximum) option

4.3.1. This option can be used when responses are not to exceed given values, however care is needed to avoid an undertest; consequently, this control option is not preferred for munition testing. Preliminary vibration survey results are used to aid the definition of the control points on the test item at which maximum response motions occur. The control points, usually two or three, will be selected using the same criteria listed in paragraph 4.4.1 for the single control point option. However, the control for:

a. Random will be based on the maximum spectrum response at any of the selected control points.

b. Sine will be based on the maximum peak response at any of the selected control points.

4.4. Single point control option

4.4.1. This option can be used when the preliminary vibration survey shows that inputs to the test item are nominally equal at each fixing point or when one control accelerometer accurately represents an average of the inputs at each fixing point. A single control point is selected from the following alternatives:

a. From amongst the fixing points.

b. In such a way that it provides the best solution for achieving the tolerances at the fixing points.

4.4.2. This option is sometimes used to limit vibration responses at a critically sensitive point on the test item. In such cases it is essential to ensure that the remainder of the test item is not undertested.

4.4.3. Small, rigid items are more suited to single point control than large complicated items.

5. TEST INFORMATION TO BE SPECIFIED

5.1. Compulsory

a. The identification of the test item.

b. The definition of the test item, eg: packaged or unpackaged.

c. The type of test: development, acceptance, etc, and the scenario simulated.

d. The orientation of the test item in relation to the test axes.

e. If operating checks are to be performed and when.

f. The vibration control strategy.

g. Control points for vibration or a procedure to select these points.

h. The definition of the test severity including test spectra and duration of test.

i. The statement of the failure criteria.

j. Any other environmental conditions at which testing is to be carried out, if other than standard laboratory conditions.

k. Possible safety implications (explosives, toxic substances, radiation hazards, etc).

5.2. If required

a. The specific features of the test assembly (vibrator, fixture, interface connections, etc).

b. The effect of gravity and the consequent precautions.

c. The pre-conditioning time.

d. The use of isolator mounts or otherwise.

e. Tolerances, if different from paragraph 6.

f. List of measurement channels and recording requirements.

6. TEST TOLERANCES AND RELATED CHARACTERISTICS

6.1. Sinusoidal vibration

6.1.1. The test facility should be able to excite the test item in the way stipulated in the Test Instruction. In these conditions the motion should be sinusoidal and such that the fixing points of the test item move substantially in phase with and parallel to the excitation axis.

6.1.2. The sinusoidal tolerances and related characteristics defined in Table 1 below (sinusoidal tolerances) should be adopted and checked with the test item installed using reduced test amplitudes as appropriate. Only under exceptional circumstances should a Test Instruction need to specify different tolerances.

6.1.3. The complete test control system should not produce uncertainties exceeding one third of the tolerance values listed in Table 1.

6.1.4. The tolerances associated with the test severity parameters are not to be deliberately used to overtest or undertest the test item.

6.1.5. If tolerances are not met, the differences observed should be noted in the test report.

TABLE 1

TOLERANCES AND RELATED CHARACTERISTICS FOR SINUSOIDAL VIBRATION

PARAMETER	TOLERANCES/CHARACTERISTICS
Critical frequencies - see Note 1	± 0.05 Hz from zero to 0.5 Hz ± 10% from 0.5 Hz to 5 Hz ± 0.5 Hz from 5 Hz to 100 Hz ± 0.5% above 100 Hz
Characteristic frequencies of the test profile - see Note 2	± 0.05 Hz from zero to 0.25 Hz ± 20% from 0.25 Hz to 5 Hz ± 1 Hz from 5 Hz to 50 Hz ± 2% above 50 Hz
Sweep rate - see Note 3	± 10%
Fundamental amplitude of vibration (displacement, velocity, acceleration)	± 15% at the control points ± 25% at the fixing points up to 500 Hz ± 50% at the fixing points above 500 Hz
Difference between the unfiltered and filtered acceleration signal - see Note 4	± 5% on RMS values
Transverse movement at the fixing points	< 50% of the movement for the specified axis up to 500 Hz. < 100% above 500 Hz (in special cases, eg: small test items, transverse movement may be limited to 25 and 50% respectively)
Test Duration	± 5%

Notes:

(1) Critical frequencies are frequencies at which test items malfunction and/or detrimental performance is exhibited due to the effects of vibration, or mechanical resonances and other response effects, such as chatter, occur.

(2) Characteristic frequencies are :
The frequency limits of the swept frequency range, or the transition frequencies of the test profile.

(3) Unless otherwise specified the vibration should be continuous and change exponentially with time at one octave per minute.

(4) A signal tolerance of 5% corresponds to a distortion of 32% by utilisation of the formula:

$$Distortion = \sqrt{\frac{a_{tot}^2 - a_1^2}{a_1}} x100$$

where a_1 = *rms value of acceleration at the driving frequency*

a_{tot} = *total rms of the applied acceleration (including the value of* a_1*)*

6.2. Random vibration

6.2.1. The test facility should be capable of exciting the equipment to the random vibration conditions specified in the Test Instruction. The motion induced by the random vibration should be such that the fixing points of the test item move substantially in parallel with the axis of excitation. In these conditions the amplitudes of motion should exhibit a normal distribution. The tolerances defined in Table 2 should be adopted and checked with the test item installed using reduced test amplitudes as appropriate.

6.2.2. Since the control loop time depends on the number of degrees of freedom and on the analysis and overall bandwidths, it is important to select these parameters so that test tolerances and control accuracy can be achieved. When possible, identical analysis bandwidths should be used for both control and monitoring. When this is not possible, due allowance should be made in the values obtained from the monitoring analysis.

6.2.3. For swept narrow band random tests the tolerances on the swept components of the test requirement should, whenever possible, be the same as for the wide band random component. In particular, the tolerances should follow the actual swept bandwidth (width only) as it sweeps, and as the sweep moves the tolerance should return to the broad band level where appropriate. Where these tolerances cannot be achieved, the tolerances for these components shall be agreed by the Responsible Authority and stated in the Test Instruction.

6.2.4. The complete test control system should not produce uncertainties exceeding one third of the tolerance values listed in Table 2.

6.2.5. The tolerances associated with the test severity parameters are not to be deliberately used to overtest or undertest the test item.

6.2.6. If tolerances are not met, the differences observed, together with the reasons for the differences, shall be noted in the test report.

TABLE 2

TOLERANCES AND RELATED CHARACTERISTICS FOR RANDOM VIBRATION

PARAMETER	TOLERANCES/CHARACTERISTICS
Number (n) of independent statistical degrees of freedom (DOF) for control of the specified ASD	$n > 50$ - see Note
RMS value of amplitude measured at the control point in the test axis	± 10% of the pre-set RMS value
Maximum local amplitude deviation of the control ASD in relation to the specified ASD	± 3 dB Above 500 Hz, locally (limited to 5% of the frequency range): ± 6 dB
Maximum variation of the RMS value at the fixing points in the test axis	± 25% of the pre-set RMS value
ASD measured with the same number of DOF as in the test axis, along the two transverse directions	Less than 100% of the specified ASD of the control point
Amplitude distribution of instantaneous values of the random vibration measured at the control point	Nominally Gaussian
Test Duration	± 5%

Note:

The number of degrees of freedom has been reduced from the normally accepted level of 100 during swept frequency narrow band random on wide band random testing. This reduction may be necessary for improved control during the frequency sweep. 100 degrees of freedom should still be used for control of wide band random vibration.

7. TEST INSTALLATION CONDITIONS

7.1. General

7.1.1. Test items can vary from munition components to structural assemblies containing several different sub-assemblies. Consequently, the installation procedures need to address the following:

a. Fixing should simulate actual in-Service mounting attachments (including vibration isolators, if appropriate).

b. All relevant safety devices, connections (cables, pipes, etc.) should be installed in such a way that they impose stresses and strains on the test item similar to those encountered in service.

7.1.2. The following should also be considered:

a. Adverse gravitational effects arising from fixing methods.

b. Vibration of the test item in more than one axis simultaneously or using more than one vibration generator to obtain a more representative simulation.

c. Suspension of test item using low frequency supports to avoid complex test fixture resonances.

7.2. Test set up

7.2.1. Unless otherwise specified, testing should be accomplished in three mutually perpendicular axes in turn with the test item oriented as during normal carriage. The test item should be hard mounted directly to the vibrator, using its normal mounting method and a suitable fixture. (The stiffness of the mounting fixture should be such that its natural frequencies are as high as possible so as to cause minimum interference with test item response.) Should gravitational effects be considered to be significant, slip tables may need to be used.

7.2.2. The fixture should transmit the excitation to the test item so as to reproduce as accurately as possible the vibration spectrum.

7.2.3. Control instrumentation should be mounted as specified in the Test Instruction, or its location and mounting determined according to a procedure included in the Test Instruction.

7.2.4. Large, complicated test items may be suspended from a structural frame. In this case the test set up shall be such that its rigid body modes (translation and rotation) are lower than the lowest test frequency. Vibration shall be applied by means of a rod or suitable mounting device running from the vibrator to a relatively hard structurally supported point on the surface of the test item.

7.3. Isolation systems

7.3.1. Materiel intended for use with vibration or shock isolation systems should normally be tested with its isolators in position. If it is not practicable to carry out the vibration test with the appropriate isolators, or if the dynamic characteristics of the equipment installation are highly variable, for example temperature dependent, then the test item should be tested without isolators at a modified severity specified by the Responsible Authority. In the case where a continuous vibration test can cause unrealistic heating of the test item and/or isolators, the excitation should be interrupted by periods of rest, which should be specified in the Test Instruction.

7.4. Munitions transported as secured cargo

7.4.1. The following additional instructions are applicable for munitions transported as secured cargo:

a. The test item shall be securely mounted in its transport configuration on the vibration fixture/table using restraints and tie-downs typical of those to be used during actual transport.

b. Testing should be conducted using representative stacking configurations.

c. The excitation should be applied through all representative axes.

8. PRE-CONDITIONING, CHECKS, FAILURE CRITERIA

8.1. Pre-conditioning

8.1.1. The test item should be stabilised to its initial climatic and other conditions as stipulated in the Test Instruction.

8.1.2. Storage and transit temperatures for the relevant climatic categories should be derived from STANAG 2895 or from measured data.

8.1.3. Minimum temperature pre-conditioning durations for munitions should be as follows:

Calibre (mm):	40	76	90	105	120	155	165	203
Duration (hr):	4	8	13	18	20	22	23	26

a. For non-cylindrical or packaged munitions use the minimum dimension instead of calibre to determine the pre-conditioning duration.

b. The above durations are the minimum to achieve the required effect, and may be extended where it is helpful to the testing agency. However, conditioning at a steady temperature will not normally occur in service and some explosives and propellants react adversely if conditioned at high temperatures for long periods. Therefore the durations should not normally be extended beyond a total of 36 hours for temperatures above 50°C.

8.1.4. It is strongly recommended that the temperatures should be maintained during the test. Exceptionally, when there is a lack of facilities, it may be acceptable only to precondition the munitions, returning them to the temperature chamber part way through the test, if necessary, to maintain the required temperature. Large munitions, with correspondingly large heat capacity, will retain heat for long periods, so interruptions to the vibration test for re-heating are unlikely to be required except for very long vibration tests.

8.2. Operational checks

8.2.1. All operational checks including all examinations should be undertaken before starting the vibration test and if appropriate during the test as stipulated in the Test Instruction.

8.2.2. Any final operational checks should be made after the test item has re-stabilised at standard ambient conditions.

8.3. Failure criteria

8.3.1 The test item shall remain safe and meet all specified performance requirements during and following the application of vibration.

9. TEST PROCEDURES

9.1. General

9.1.1. Conduct the relevant test procedure in accordance with the Test Instruction.

9.1.2. Test specifiers are reminded that control system difficulties may be encountered when exciting the test item to complex vibration test types such as those adopted by this test method. When using less sophisticated control systems it may be possible to specify incompatible sweep rates and control strategies; for example, through demanding excessive numbers of statistical degrees of freedom and/or control points. In these cases the control system may, without warning, perform the test incorrectly, in that sweeps may not be completed or that tolerances may be exceeded. Therefore the following two safeguards shall be applied for all tests.

a. Verify, prior to undertaking the test, that the control system is capable of conducting the test as specified in the Test Instruction. Where any doubt remains as to the suitability of the control system to undertake the test, the advice of an independent specialist should be sought. (Advice on verifying control system suitability will be developed for a future edition of this AOP.)

b. Record in the Test Report any deficiencies identified in the performance of the control system when undertaking this particular test, and especially those which could produce a deviation from the requirements specified in the Test Instruction.

9.1.3. Record in the Test Report any test deviations together with their reasons. For example, sometimes exciters cannot achieve the full displacement requirements or exciter amplifiers cannot adequately drive the exciter at the low or high frequencies.

9.2. Test procedure

9.2.1. The test procedure is identical for both generic test types, that is, for swept frequency narrow band random vibration on wide band random vibration and for swept frequency sinusoidal vibration on wide band random vibration.

Step 1 - Pre-condition (paragraph 8.1) as specified.

Step 2 - Implement the control strategy, including control and monitoring points (paragraph 4), with due regard to the safeguards stated in paragraph 9.1 above. This Step is conducted at a low vibration level, or alternatively with a structural dynamic representation of the test item. This Step may also include the determination of any critical frequencies.

Step 3 - Undertake the initial operational checks (paragraph 8.2).

Step 4 - Subject the test item to the test severity specified, (paragraph 10) and conduct any operational checks specified.

Step 5 - Undertake the final operational checks.

Step 6 - Repeat Steps 1 to 5 for any other specified test axes.

Step 7 - Record the information required.

10. TEST SEVERITIES

10.1. The vibration severities for munitions are presented in Figures 1 to 4. The severities shown are related to munition transport and installed configuration and also to vehicle location. The effects of parameters such as terrain type are included in the severities. The figures cover test type (a) - swept frequency narrow band vibration on wide band random vibration and test type (b) - swept frequency sinusoidal vibration on wide band random vibration. Severities selected from the figures are considered suitable for use in acceptance tests. The titles and content of Figures 1 to 4 cover the severity categories as listed in paragraph 2.3.2. In addition, Figure 2 contains severities for munitions installed in racks within turrets and severities for roof mounted munitions.

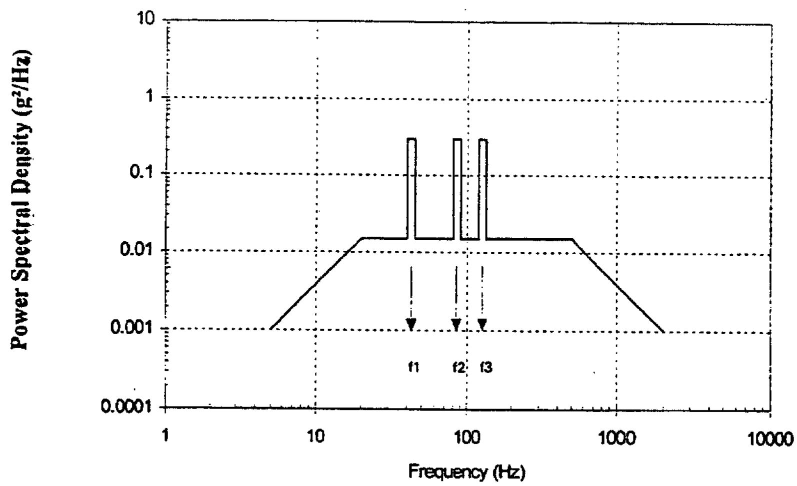
10.2. It is necessary to quote two vibration test severities (Levels 1 and 2) for munitions on sponsons or installed directly in hulls (refer to Figures 3 and 4). The higher severity (Level 2) should be considered a "fall back" level and is to be adopted unless the munitions are to be installed in a vehicle for which it can be demonstrated, eg: by measurement or precedent, that its vibration severities are no higher than those of the lower severity (Level 1).

10.3. For standardisation purposes it is important that the severities shown in Figures 1 to 4 are adopted whenever possible. Adjustments to levels are permissible to incorporate necessary increases following an evaluation of measured data.

10.4. The test amplitudes are considered to represent maximum acceptable limits. Consequently, any additional factoring to shorten test durations, or to obtain more Service mileage for the same test duration, is strictly not recommended since unrepresentative failures could be expected to result.

10.5. The amplitude distribution of the wide band random vibration component of a typical tracked vehicle environment is unlikely to be Gaussian. In practice this means that the peak accelerations generated by a vibrator during laboratory testing will be lower than those observed from field measured data. Therefore, as it is important to ensure that the test includes the maximum observed vibration amplitudes, it is often necessary to compensate for this deficiency. A suitable compensation technique is given in Annex B, paragraph B.3.

Figure 1: Munitions transported as secured cargo



The bandwidths of the harmonically related narrow bands are:

f_1=5Hz,
f_2=10Hz,
f_3=15Hz.

The swept frequency ranges of the narrow bands are:

20 <f_1 <170Hz,
40 <f_2 <340Hz,
60 <f_3 <510Hz.

Figure 1 - Notes:

1. **Wideband random spectrum amplitudes (g²/Hz)**

Axis	Spectrum breakpoints - frequency (Hz)			
	5	20	510	2000
Vertical	0.001	0.015	0.015	0.001
Transverse	0.001	0.010	0.010	0.001
Longitudinal	0.001	0.010	0.010	0.001

2. **Swept narrow band random amplitudes (g²/Hz)**

Axis	Harmonically related swept frequencies (Hz)		
	f_1*	f_2	f_3
Vertical	0.300	0.300	0.300
Transverse	0.150	0.150	0.150
Longitudinal	0.150	0.150	0.150

*When sweeping up the frequency range, the value of f_1 may be ramped up from 0.08 g²/Hz at 20 Hz to the specified value at 40 Hz, and vice-versa when sweeping down the frequency range.

3. **Sweep rate and band**
The sweep rate should be within the range one half to one octave per minute. Minimum number of sweeps = 2, ie: one sweep up the frequency range followed by one sweep down the frequency range. When the centre frequency of the first harmonically related sweeping band (f_1) is at its lowest frequency, the lower frequency band edge of this sweeping band and the lower band edge of the 0.015 g²/Hz level wideband coincide at 20 Hz. When the centre frequency of the third harmonically related sweeping band (f_3) is at its highest frequency, the upper band edge of this sweeping band and the upper band edge of the 0.015 g²/Hz level wideband coincide at 510 Hz.

4. **Test duration**

For most applications a total test duration of 2 hours per axis should be sufficient to accommodate the life of a munition transported as secured cargo. In the event that a munition will be installed in racks within tracked vehicles for a relatively short Service distance then a test duration based on 45 minutes per axis per 160 km (100) miles of Service distance should be used.

5. **Swept sine wave amplitudes (g peak)**

(Alternative to swept narrow band random)

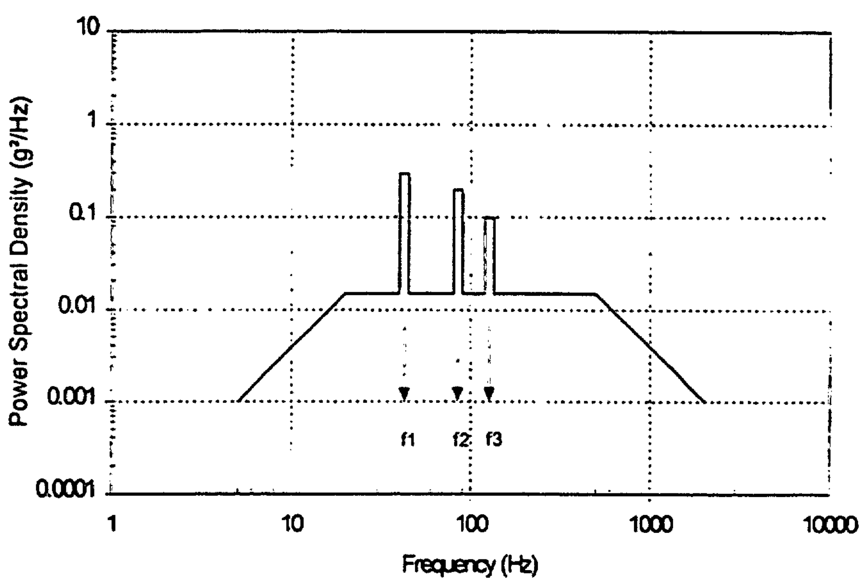
Axis	Harmonically related swept frequencies (Hz)		
	f_1*	f_2	f_3
Vertical	1.75	2.45	3.00
Transverse	1.25	1.75	2.13
Longitudinal	1.25	1.75	2.13

*When sweeping up the frequency range, the value of f_1 may be ramped up from 0.9 g pk at 20 Hz to the specified value at 40 Hz, and vice-versa when sweeping down the frequency range.

6. **RMS values (g)**

Axis	Harmonically related swept frequencies (Hz)			Wideband	Total
	f_1	f_2	f_3		
Vertical	1.22	1.73	2.12	3.56	4.65
Transverse	0.87	1.22	1.50	3.03	3.70
Longitudinal	0.87	1.22	1.50	3.03	3.70

Figure 2: Munitions installed in bustle racks or directly in turrets



The bandwidths of the harmonically related narrow bands are:

f_1 = 5 Hz,
f_2 = 10 Hz,
f_3 = 15 Hz.

The swept frequency ranges of the narrow bands are:

20 < f_1 < 170 Hz,
40 < f_2 < 340 Hz,
60 < f_3 < 510 Hz.

Figure 2 - Notes:

1. **Wideband random spectrum amplitudes (g^2/Hz)**

Axis	Spectrum breakpoints - frequency (Hz)			
	5	20	510	2000
Vertical	0.001	0.015	0.015	0.001
Transverse	0.001	0.010	0.010	0.001
Longitudinal	0.001	0.010	0.010	0.001

2. **Swept narrow band random amplitudes (g^2/Hz)**

Axis	Harmonically related swept frequencies (Hz)		
	f_1*	f_2	f_3
Vertical	0.30	0.20	0.10
Transverse	0.15	0.10	0.05
Longitudinal	0.15	0.10	0.05

***When sweeping up the frequency range, the value of f_1 may be ramped up from 0.08 g^2/Hz at 20 Hz to the specified value at 40 Hz, and vice-versa when sweeping down the frequency range.**

3. **Sweep rate and band**
The sweep rate should be within the range one half to one octave per minute. Minimum number of sweeps = 2, ie: one sweep up the frequency range followed by one sweep down the frequency range. When the centre frequency of the first harmonically related sweeping band (f_1) is at its lowest frequency, the lower frequency band edge of this sweeping band and the lower band edge of the 0.015 g^2/Hz level wideband coincide at 20 Hz. When the centre frequency of the third harmonically related sweeping band (f_3) is at its highest frequency, the upper band edge of this sweeping band and the upper band edge of the 0.015 g^2/Hz level wideband coincide at 510 Hz.

4. **Test duration**
For most applications a total test duration of 4 hours per axis should be sufficient to accommodate the life of a munition installed in bustle racks or turrets. In the event that a munition will be installed in racks within tracked vehicles for a relatively short Service distance then a test duration based on 45 minutes per axis per 1600 km (1000) miles of Service distance should be used.

5. **Swept sine wave amplitudes (g peak)**

(Alternative to swept narrow band random)

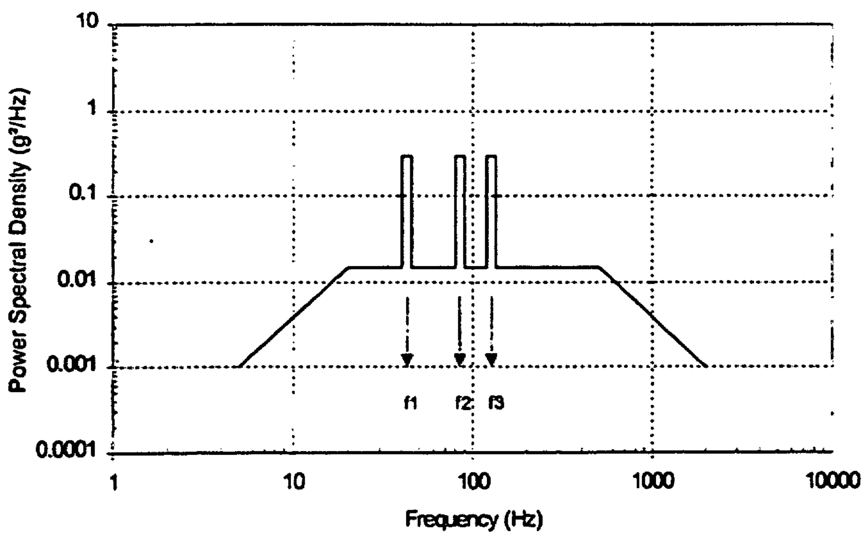
Axis	Harmonically related swept frequencies (Hz)		
	f_1*	f_2	f_3
Vertical	1.75	2.00	1.75
Transverse	1.25	1.50	1.25
Longitudinal	1.25	1.50	1.25

*When sweeping up the frequency range, the value of f_1 may be ramped up from 0.9 g pk at 20 Hz to the specified value at 40 Hz, and vice-versa when sweeping down the frequency range.

6. **RMS values (g)**

Axis	Harmonically related swept frequencies (Hz)			Wideband	Total
	f_1	f_2	f_3		
Vertical	1.22	1.41	1.22	3.56	4.20
Transverse	0.87	1.00	0.87	3.03	3.42
Longitudinal	0.87	1.00	0.87	3.03	3.42

Figure 3: Munitions installed in racks within hulls
(also munitions on sponsons or installed directly in hulls - Level 1)



The bandwidths of the harmonically related narrow bands are:

f_1 = 5 Hz,
f_2 = 10 Hz,
f_3 = 15 Hz.

The swept frequency ranges of the narrow bands are:

$20 < f_1 < 170$ Hz,
$40 < f_2 < 340$ Hz,
$60 < f_3 < 510$ Hz.

Figure 3 - Notes:

1. **Wideband random spectrum amplitudes (g^2/Hz)**

Axis	Spectrum breakpoints - frequency (Hz)			
	5	20	510	2000
Vertical	0.001	0.015	0.015	0.001
Transverse	0.001	0.010	0.010	0.001
Longitudinal	0.001	0.010	0.010	0.001

2. **Swept narrow band random amplitudes (g^2/Hz)**

Axis	Harmonically related swept frequencies (Hz)		
	f_1*	f_2	f_3
Vertical	0.300	0.300	0.300
Transverse	0.150	0.150	0.150
Longitudinal	0.150	0.150	0.150

*When sweeping up the frequency range, the value of f_1 may be ramped up from 0.08 g^2/Hz at 20 Hz to the specified value at 40 Hz, and vice-versa when sweeping down the frequency range.

3. **Sweep rate and band**
The sweep rate should be within the range one half to one octave per minute. Minimum number of sweeps = 2, ie: one sweep up the frequency range followed by one sweep down the frequency range. When the centre frequency of the first harmonically related sweeping band (f_1) is at its lowest frequency, the lower frequency band edge of this sweeping band and the lower band edge of the 0.015 g^2/Hz level wideband coincide at 20 Hz. When the centre frequency of the third harmonically related sweeping band (f_3) is at its highest frequency, the upper band edge of this sweeping band and the upper band edge of the 0.015 g^2/Hz level wideband coincide at 510 Hz.

4. **Test duration**
For most applications a total test duration of 4 hours per axis should be sufficient to accommodate the life of a munition installed in racks within hulls. In the event that a munition will be installed in racks within tracked vehicles for a relatively short Service distance then a test duration based on 45 minutes per axis per 1600 km (1000) miles of Service distance should be used.

5. **Swept sine wave amplitudes (g peak)**
(Alternative to swept narrow band random)

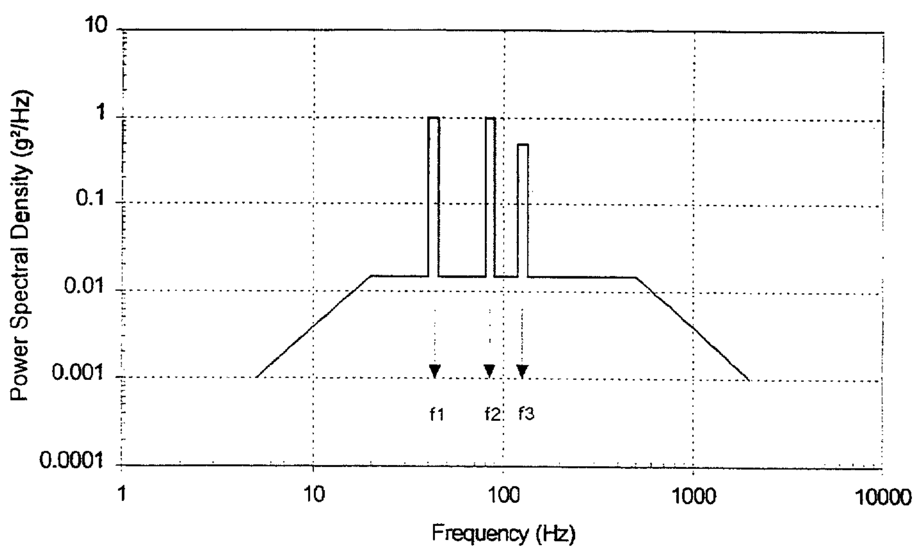
Axis	Harmonically related swept frequencies (Hz)		
	f_1*	f_2	f_3
Vertical	1.75	2.45	3.00
Transverse	1.25	1.75	2.13
Longitudinal	1.25	1.75	2.13

*When sweeping up the frequency range, the value of f_1 may be ramped up from 0.9 g pk at 20 Hz to the specified value at 40 Hz and vice-versa when sweeping down the frequency range.

6. **RMS values (g)**

Axis	Harmonically related swept frequencies (Hz)			Wideband	Total
	f_1	f_2	f_3		
Vertical	1.22	1.73	2.12	3.56	4.65
Transverse	0.87	1.22	1.50	3.03	3.70
Longitudinal	0.87	1.22	1.50	3.03	3.70

Figure 4: Munitions on sponsons or installed directly in hulls - Level



The bandwidths of the harmonically related narrow bands are:

f_1 = 5 Hz,
f_2 = 10 Hz,
f_3 = 15 Hz.

The swept frequency ranges of the narrow bands are:

20 < f_1 < 170 Hz,
40 < f_2 < 340 Hz,
60 < f_3 < 510 Hz.

Figure 4 - Notes:

1. **Wideband random spectrum amplitudes (g^2/Hz)**

Axis	Spectrum breakpoints - frequency (Hz)			
	5	20	510	2000
Vertical	0.001	0.015	0.015	0.001
Transverse	0.001	0.010	0.010	0.001
Longitudinal	0.001	0.010	0.010	0.001

2. **Swept narrow band random amplitudes (g^2/Hz)**

Axis	Harmonically related swept frequencies (Hz)		
	f_1*	f_2	f_3
Vertical	1.00	1.00	0.50
Transverse	1.00	0.50	0.25
Longitudinal	1.00	0.50	0.25

*When sweeping up the frequency range, the value of f_1 may be ramped up from 0.25 g^2/Hz at 20 Hz to the specified value at 40 Hz, and vice-versa when sweeping down the frequency range.

3. **Sweep rate and band**
The sweep rate should be within the range one half to one octave per minute. Minimum number of sweeps = 2, ie: one sweep up the frequency range followed by one sweep down the frequency range. When the centre frequency of the first harmonically related sweeping band (f_1) is at its lowest frequency, the lower frequency band edge of this sweeping band and the lower band edge of the 0.015 g^2/Hz level wideband coincide at 20 Hz. When the centre frequency of the third harmonically related sweeping band (f_3) is at its highest frequency, the upper band edge of this sweeping band and the upper band edge of the 0.015 g^2/Hz level wideband coincide at 510 Hz.

4. **Test duration**
For most applications a total test duration of 4 hours per axis should be sufficient to accommodate the life of a munition installed directly in hulls. In the event that a munition will be installed in racks within tracked vehicles for a relatively short Service distance then a test duration based on 45 minutes per axis per 1600 km (1000 miles) of Service distance should be used.

5. **Swept sine wave amplitudes (g peak)**
(Alternative to swept narrow band random)

Axis	Harmonically related swept frequencies (Hz)		
	f_1*	f_2	f_3
Vertical	3.00	4.50	4.00
Transverse	3.00	3.00	2.75
Longitudinal	3.00	3.00	2.75

*When sweeping up the frequency range, the value of f_1 may be ramped up from 1.5 g pk at 20 Hz to the specified value at 40 Hz, and vice-versa when sweeping down the frequency range.

6. **RMS values (g)**

Axis	Harmonically related swept frequencies (Hz)			Wideband	Total
	f_1	f_2	f_3		
Vertical	2.24	3.16	2.74	3.56	5.93
Transverse	2.24	2.24	1.94	3.03	4.79
Longitudinal	2.24	2.24	1.94	3.03	4.79

CHARACTERISTICS OF THE ENVIRONMENT

A.1. GENERAL

A.1.1. This annex addresses the characteristics of mechanical environments that may be encountered by munitions when installed in tracked vehicles.

A.1.2. When a tracked vehicle moves across a terrain, interactions between the vehicle's tracks and the terrain result in vibration excitation being transmitted to the vehicle's installed materiel via the suspension system and hull structure. Vibration is also generated by the action of the tracks moving over their wheels, sprockets and rollers (Figure A1 refers) which can pass directly into the vehicle's hull. In addition, materiel will experience inertial loadings arising from the vehicle's acceleration, eg: when increasing speed, braking, cornering, etc.

A.1.3. The action of the vehicle's engine, transmission, pumps, etc., can also give rise to vibration, which is likely to be most significant at discrete frequencies associated with rotating shafts, gear meshing, etc. The significance of these excitations is strongly dependent on a munition's position relative to these sources.

A.1.4. Vibration spectra acquired from measurements on tracked vehicles comprise a wide band random spectrum upon which is superimposed a number of relatively low frequency peaks. An example of such a spectrum is shown in Figure A2. The impact of successive track plates on the ground is perceived within the vehicle as narrow band spectral components, which can be severe. These narrow band components are speed dependent and relate to the fundamental track patter frequency and usually several higher harmonics. The wide band component is generated by the combined effects of the rolling of the wheels on the tracks, interactions between the track links and the various other sources including engine, gearbox, generators, etc. Peaks in response frequencies corresponding to the vehicle's suspension system can be expected to be low, eg: <3 Hz. Relatively wide band peaks in frequencies may also be evident corresponding to structural dynamic modes of the vehicle itself. These modes may lie in the 20 to 100 Hz frequency range.

A.2. TERRAIN TYPE

A.2.1. The nature of terrain experienced by a tracked vehicle will significantly influence munition response. Terrains which may need to be considered depend upon the vehicle's role, and could include metalled roads, rough roads, pavé, etc, in addition to cross-country. As noted above, the action of the track plates impacting on the ground is a major source of vibration. Therefore hard surfaces, including metalled roads, are likely to provide a more severe environment than softer terrains such as cross country, which tend to cushion the impact of track links on contact with the ground. This is in contrast to the trend associated with wheeled vehicles, which produce relatively benign vibration loadings on metalled roads. An example for a tracked vehicle of how vibration responses, expressed as overall g rms, vary with respect to terrain type, is shown in Figure A3.

A.3. VEHICLE TYPE

A.3.1. The vibration environment associated with main battle tanks is particularly severe. The contributing factors are the stiffness of their suspension systems, their overall structural rigidity and lack of damping, their powerful engines and track systems.

A.3.2. Other tracked armoured fighting vehicles (AFV) tend to produce a similar dynamic environment to that of main battle tanks but the severity is dependent upon vehicle design.

A.3.3. Logistics vehicles are not armoured and are often based on standard chassis designs. The vibration severity of these vehicles is likely to reflect the design aims of their chassis, which may be to meet either commercial or military requirements. The vibration environment for logistics vehicles built on military chassis would be expected to be more severe than those built on commercial chassis because of their relatively high suspension system stiffness and structural rigidity.

A.4. VEHICLE TRACK PLATES

A.4.1. The type of track plates fitted to a tracked vehicle is a major influence on the vibration environment within the vehicle. Two aspects of plate design can influence vibration severity.

a. Plate connections: A number of different designs are used to connect the plates together. Recent work has shown that for AFVs, hull vibration in terms of the overall g rms (0 to 1000 Hz) associated with a dry pin design of track is up to two times as severe as that associated with end connector track. See illustrations at Figures A4 and A5.

b. Plate facings: The type of facing fitted to the metal track plates should reflect the type of terrain that a vehicle may be expected to encounter. For example, rubber facings are often used when a vehicle is to spend a high proportion of its time on classified roads. Whilst these are fitted to avoid damage to the road surface by the track, a secondary effect is to reduce significantly the severity of track patter vibration.

A.5. VEHICLE AGILITY

A.5.1. The agility of a vehicle is related to its power to weight ratio. Modern AFVs tend to have high power to weight ratios and are therefore capable of high speeds (greater than 60 km/h). As vibration severity tends to increase with speed, there is reason to expect that high power to weight ratio vehicles will produce an increase in the severity of the dynamic environments. High speeds will also extend track patter harmonics.

A.6. MUNITION POSITION AND MOUNTING

A.6.1. The severity of the environment perceived by a munition installed in a vehicle depends on where the munition is mounted. Evidence suggests that hull vibration, expressed as the overall g rms (0 to 1000 Hz), can be between 1.3 and 5.7 times more severe than in the turret, depending on vehicle type and measurement axis. With respect to the relative severity of axes, vibration in the vertical axis in the hull or turret has been seen to be around 1.5 times more severe than in the transverse or longitudinal axes. A munition's mass and mounting arrangements can also influence its response.

A.7. VEHICLE OPERATIONAL SPEEDS

A.7.1. In general, vehicle structural vibration severity can be expected to increase as vehicle speed increases but g rms levels do not increase linearly with speed.

A.7.2. If resonances are excited, the maximum vibration responses of a particular installed equipment do not necessarily occur at the vehicle's maximum speed. Such resonances could be associated with the vehicle's structure, the particular item of equipment or its mounting arrangements.

A.8. VEHICLE OPERATIONAL MANOEUVRES

A.8.1. Recent work indicates that for AFVs, vibration during cornering is considerably more severe than when travelling in a straight line, eg: by up to 2 times for the hull and up to 2.5 times in the turret in terms of the overall g rms (0 to 1000 Hz).

A.9. LAUNCH OF WEAPONS AND GUNFIRE

A.9.1. The launch of weapons and the firing of guns can subject the vehicle to high levels of shock, vibration and blast pressure. These conditions are highly specific to particular installations and therefore generalised guidance is inappropriate.

A.10. FAILURE MODES

A.10.1. Failure modes in munitions caused by vibration or shock may be divided into the following two general types:

a. Fracture: Fracture of material, explosive or non-explosive, may occur as a result of a single excursion or following a number of excursions ie: fatigue.

b. Friction: Adjacent materials, where one or both has some freedom to move, may rub together causing hot spots. If one or both materials are explosive, initiation of an explosive event may occur. Alternatively the friction may cause wearing away of material, possibly weakening it to such an extent that it fails, or the increased tolerances cause rattle with subsequent failure elsewhere.

A.10.2. Failure not falling directly into the above categories, but associated with one or both are:

a. Inadequately restrained munitions may impact with each other or with other parts of the vehicle causing damage possibly leading to failure. (The restraint system may have been inadequate initially or may have become so during the test.)

b. Electrical connectors may become loose leading to a break in continuity.

c. Inertial loadings on piezoelectric crystals may cause spurious electrical signals.

A.10.3. As tracked vehicle operations can induce high levels of vibration in installed munitions, potentially, any of the above failure modes could occur. A primary area of concern is of possible coupling between vehicle excitation at track patter frequencies and the response of munition support equipment, ie: associated with the munition itself or its mounting arrangement. As the fundamental track patter frequency varies up to 150 Hz, according to vehicle speed and vehicle type, it can be difficult to avoid such coincidences at all times. This problem is exacerbated when strong harmonics of track patter are evident.

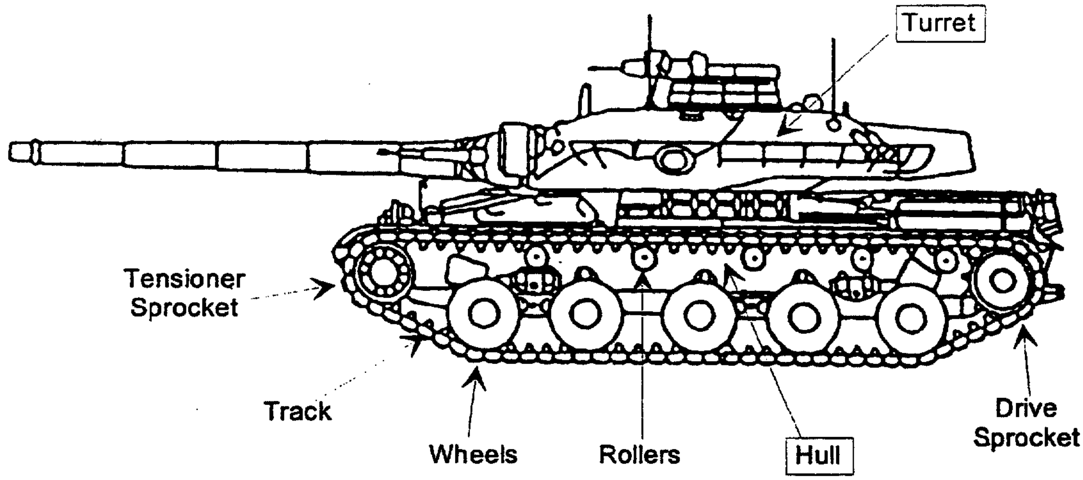


Figure A1 - Equipment mounting zones and track features for a main battle tank

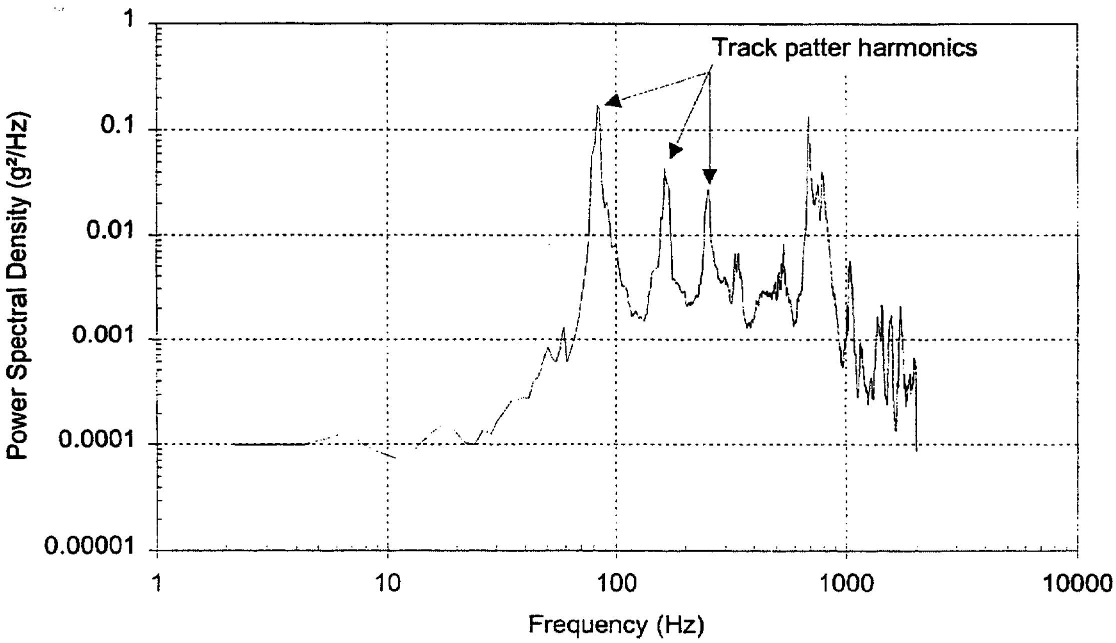


Figure A2 - Vibration spectrum for a tracked vehicle

Notes:

(1) Data from the hull of an armoured fighting vehicle running on a Tarmacadam surface at 50 km/h.

(2) Spectrum is equivalent to 3.25 g rms (vertical axis).

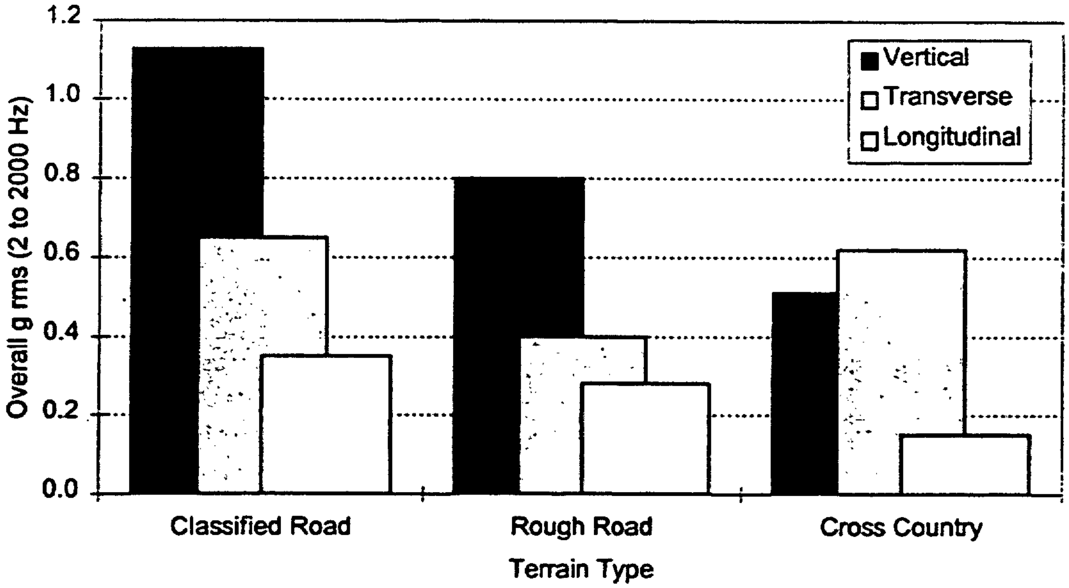
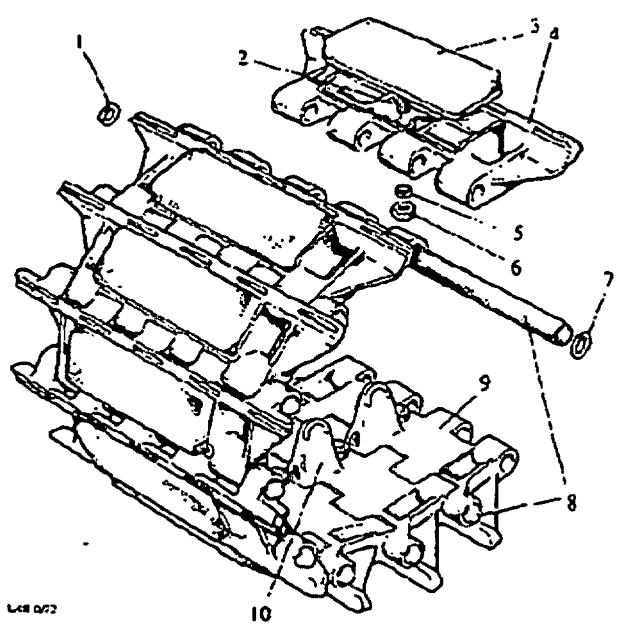


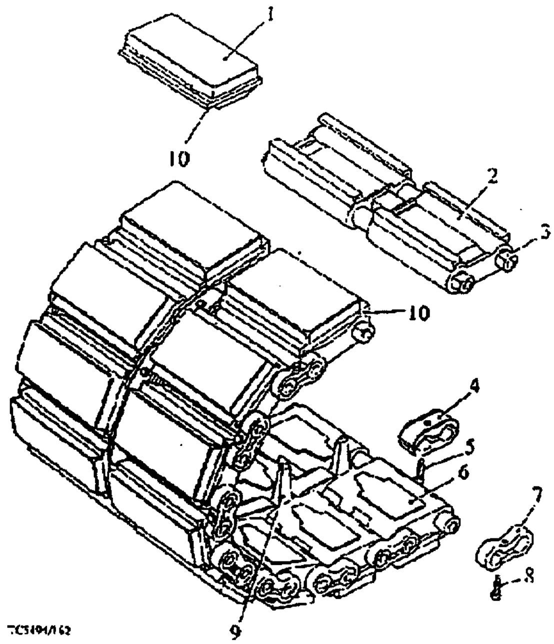
Figure A3 - Relative severity of terrains for a tracked vehicle



Key

1. Circlip
2. Retaining bolt
3. Rubber pad
4. Link grouser
5. Lock washer
6. Nut
7. Circlip
8. Track pin
9. Track pin lugs
10. Horn

Figure A4 - Dry pin track type



Key

1. Track pad
2. Track link
3. Track pin
4. Centre connector
5. Screw
6. Rubber insert moulding
7. End connector
8. Screw
9. Horn
10. Projection

Figure A5: End connector track type

DERIVATION OF SEVERITIES FROM MEASURED DATA

B.1. DERIVATION OF AN ENVIRONMENT DESCRIPTION

B.1.1. Requirements

It is first necessary to establish from the relevant requirements the type of tracked vehicle in which the munitions are to be installed, the role of the vehicle and the terrains over which it will travel, the vehicle's operating speeds, and the location of the munitions in the vehicle. Having established the requirements, relevant vibration data may be acquired from data banks, should the data exist, or from field measurement trials.

B.1.2. Environment descriptions

An environment description for an equipment installed in a tracked vehicle should generally include for each relevant terrain over the range of operating speeds, frequency response characteristics, amplitude probability plots, and time histories of any transients. This information will be used to examine trends, such as how severity is influenced by terrain and vehicle speed. The flow diagram outlined in Figure B1 points out the steps to be adopted to derive an environment description from measured data. This diagram enables frequency response characteristics and dynamic response amplitudes to be quantified for all relevant test conditions. A process for using these components of the environment description to produce test spectra and durations is discussed below.

B.2. DERIVATION OF VIBRATION TEST SEVERITIES

B.2.1. General

Test severities are defined in terms of the characteristics and amplitudes of the wide band background vibration, narrow band components associated with track patter, and durations. Advice on establishing these parameters is given below.

B.2.2. Wide band component

a. Characteristics: In general, it can be expected that the wide band component spectral characteristics, ie: the shape of ASD plots, will be stable with respect to many parameters, including vehicle speed and terrain type.

b. Amplitude: The severity of the test spectrum may not in general be obtained directly from ASDs because, for tracked vehicles, they are unlikely to be an adequate description of the environment. This is a consequence of the character of this type of data; it can be non-stationary resulting in relatively high peak to rms ratios. It is therefore also non-Gaussian. These properties of non-stationary and non-Gaussian behaviour are in contrast to the character of vibration generated in test laboratories. Consequently, special steps may need to be taken to avoid under-testing in the laboratory. In some cases sufficient conservatism can be incorporated into the test spectrum by the technique of enveloping to produce an adequate test severity. An alternative approach is to use amplitude probability distributions (APD) as the basic measure of severity and to derive appropriate factors which can then be applied to mean spectra. The APD approach is preferred for tracked vehicles and an example of its use is given in paragraph B.3.

B.2.3. Narrow band components

a. Characteristics: The frequency of the narrow band components at a given speed can be calculated from knowledge of the track pitch dimension, and can be expected to be easily recognisable in measured data, at least for hard terrains and under constant speed conditions. To accommodate these effects in a test spectrum, acknowledging that the frequencies of these components are speed dependent, the narrow bands should be swept over an appropriate frequency range. Alternatively, the wide band spectrum could simply be shaped to accommodate these peaks, rendering the narrow bands unnecessary, albeit at the considerable risk of excessive testing.

b. Amplitudes: Establishing the amplitudes of these components can be a problem because of their changing frequency with vehicle speed. This can lead to an under-estimation of severity because of averaging effects implicit in an ASD analysis. One solution is to gather data at a number of constant speeds which can then be analysed separately. Alternatively, if the speed is not constant throughout a record, evolutionary spectra (waterfall plots) can be used. In either case, the severity, expressed in either ASD or RMS form, should be associated with the resolution bandwidth to make the definition unambiguous.

B.2.4 Test duration

Test durations should be based upon the required life of a munition and the usage profile of the relevant tracked vehicle. In order to avoid impracticably long test durations, it is general practice to invoke equivalent fatigue damage laws such as Miner's Rule. This rule is also known as the "Exaggeration Formula" and is expressed as follows:

$$t_2 = t_1 (S_1/S_2)^n$$

where
t_1 = the actual duration at the measured level
t_2 = the equivalent duration at the test level
S_1 = the rms level of the measured spectrum
S_2 = the rms level of the test spectrum
n = the exaggeration exponent (values between 5 and 8 are generally acceptable dependent upon the material and construction methods used)

Suppose that 40 hours of clearance is required for a munition which experiences a measured S_1 of 1.735. Let the test spectrum have a value of S_2 of 2.7.

$$t_2 = 40(1.735/2.7)^5$$
= 4 hours 26 minutes - this is the required test duration.

(If ASD levels are used in place of rms levels then the preferred values of n are between 2.5 and 4.0.)

The exaggeration exponent is the slope of the fatigue (S/N) curve for the appropriate material. This expression is applicable to metallic materials such as steels and aluminium alloys which possess an essentially linear stress-strain relationship. This expression is used with less confidence with non-linear materials and composites. In such cases engineering judgment must be used. Although the expression has been shown to have some merits when applied to weapon systems, it should be used for munitions with extreme caution. If unrepresentative failures are to be avoided, on no account should test levels be increased beyond the maximum levels that a munition might be expected to experience during its Service life.

Furthermore, where there is evidence when carried or installed that the munition is not fully secured to the vehicle then Miner's Rule is totally invalid and should not be used. In such cases the Loose Cargo Test (STANAG 4370, AECTP-400, Method 401 Loose Cargo) should be considered as an alternative.

A simplified example of the derivation of a test duration using Miner's Rule is given below:

Terrain	Speed (km/h)	Severity index	Duration	Time	
			%	Actual t_1	Equivalent t_2
Pavé	40	1.0	5.0	3	3.00
Pavé	32	0.7	6.7	4	0.67
Rough road	24	0.6	13.3	8	0.62
Cross country	56	0.5	16.7	10	0.31
Main road	72	0.4	30.0	18	0.18
Main road	56	0.3	20.0	12	0.03
Main road	<32	0.2	8.3	5	<0.01
		Totals:	100.0	60	4.82

Notes

(1) 4.82 minutes test is equivalent to 60 minutes real time tracked vehicle vibration.

(2) The "Severity Index" for a terrain is the overall g rms normalised with respect to the maximum measured overall g rms (associated with pavé in this example). It is important to check that the ASD spectrum profile associated with the reference level (again, pavé in this example) either reflects, or is modified to reflect, the maximum amplitudes observed over the total frequency range.

(3) This method of calculating test durations would normally be applied subject to a maximum of 17 hours per axis.

B.3 COMPARING MEASURED DATA WITH TEST SPECIFICATIONS

B.3.1 When comparing measured spectra from a vehicle trial with that contained in a test specification or generated by test house equipment, care must be taken to avoid an under-estimation of the severity of the measured data. This is because of the different amplitude distributions and peak to rms ratios of these types of data. These differences can be compensated for, as shown in the example overleaf.

Measured peak amplitude probability distribution level (at the 1 in 500 occurrence level, ie: 2.88 sigma) 9.0 g

Equivalent gaussian rms $\frac{9.00}{2.88}$ = 3.1 g rms

Measured non-gaussian rms = 1.4 g rms

Factor on measured g rms $\frac{3.1}{1.4}$ = 2.2

Factor on measured ASD = 2.2^2 = 4.84

This analysis indicates that in this instance a factor of 4.84 should be applied to the measured ASD levels. When deriving test duration this level relates to less than 0.2% of the measured condition.

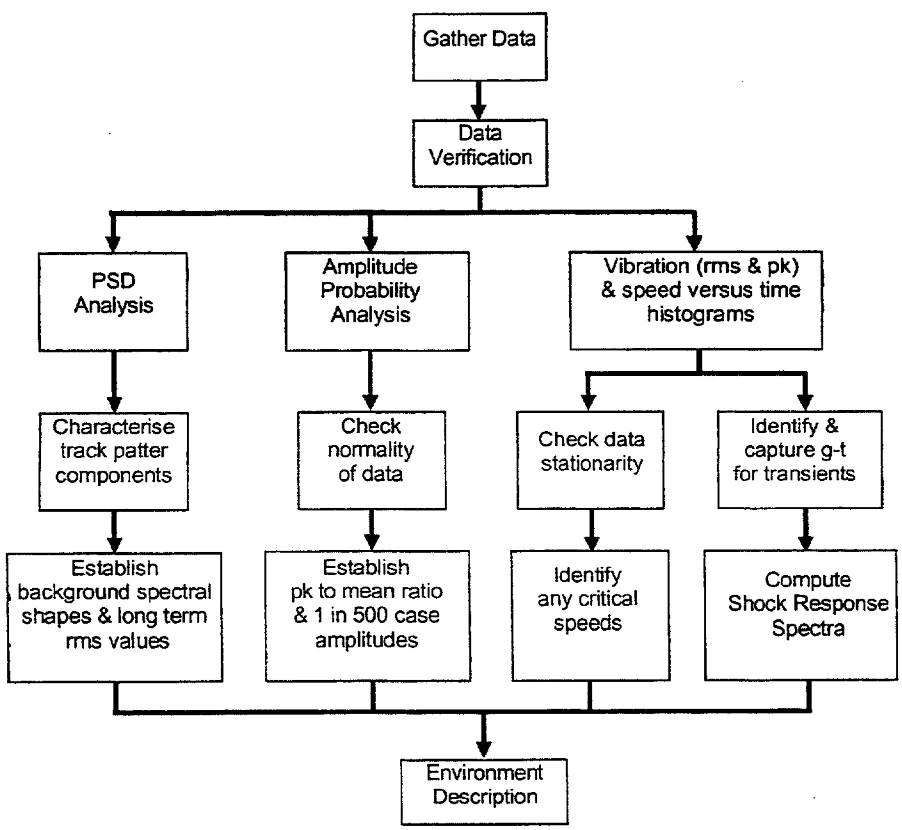


Figure B1: Derivation of an environmental description from measured data

Note:

The steps described above would normally be carried out for each terrain and for all relevant installations.

DEFINITIONS

LOOSE CARGO MUNITION

Any munition which is carried on the vehicle floor, in racking or in some arrangement in which it has some freedom, however slight, to bounce, scuff, or collide with other items being carried or other parts of the vehicle.

INSTALLED MUNITION

Any munition which has been designed to be a long term fixture in a vehicle, mounted directly to the vehicle structure with or without anti-vibration mounts or isolators.

SECURED CARGO MUNITION

Any munition which is firmly attached to the vehicle structure with or without anti-vibration mounts or isolators but which will be removed or deployed from the vehicle at some stage. This carriage will be of relatively short duration compared with installed munitions.